Designation: D2671 – 13

Standard Test Methods for Heat-Shrinkable Tubing for Electrical Use[1]

This standard is issued under the fixed designation D2671; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope*

1.1 These test methods cover the testing of heat-shrinkable tubing used for electrical insulation. Materials used include poly(vinyl chloride), polyolefins, fluorocarbon polymers, silicone rubber, and other plastic or elastomeric compounds.

1.2 The procedures appear in the following sections:

Procedure	Sections	ASTM Method Reference
Adhesive Peel Strength	98 – 104	
Brittleness Temperature	40	D746
Color	55 and 56	D1535
Color Stability	57 – 62	D1535
Conditioning	7	D618
Copper Stability	93	
Corrosion Testing	89 – 95	
Dielectric Breakdown	20 – 25	D149
Dimensions	8 – 13	D876
Flammability	68 – 72	D876
Fluid Resistance	63 – 67	
Fungus Resistance	104 – 108	
Heat Resistance	49 – 54	
Heat Shock	26 – 30	
Low-Temperature Properties	36 – 43	
Restricted Shrinkage	14 – 19	
Selection of Test Specimens	6	
Secant Modulus	81 – 84	D882
Storage Life	31 – 35	
Specific Gravity	73 and 74	D792
Stress Modulus	85 – 88	D412
Tensile Strength and Ultimate Elongation	44 – 48	D412
Thermal Endurance	96 and 97	
Volume Resistivity	75 – 78	D257
Water Absorption	79 and 80	D570
Melting Point	104 – 108	D3418

1.3 This is a fire-test-response standard.

1.4 The values stated in inch-pound units are to be regarded as standard, except for temperature, which shall be expressed in degrees Celsius. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For specific hazard statements, see Sections 5 and 68.2.

NOTE 1—These test methods are similar, but not identical to, those in IEC 60684–2 (see also Note 9).

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D149 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies
D257 Test Methods for DC Resistance or Conductance of Insulating Materials
D412 Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension
D570 Test Method for Water Absorption of Plastics
D618 Practice for Conditioning Plastics for Testing
D746 Test Method for Brittleness Temperature of Plastics and Elastomers by Impact
D792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
D876 Test Methods for Nonrigid Vinyl Chloride Polymer Tubing Used for Electrical Insulation
D882 Test Method for Tensile Properties of Thin Plastic Sheeting
D1535 Practice for Specifying Color by the Munsell System
D1711 Terminology Relating to Electrical Insulation
D3418 Test Method for Transition Temperatures and Enthalpies of Fusion and Crystallization of Polymers by Differential Scanning Calorimetry
E176 Terminology of Fire Standards

2.2 *Other Documents:*

MIL-STD 104 Limits for Electrical Insulation Color[3]

[1] These test methods are under the jurisdiction of ASTM Committee D09 on Electrical and Electronic Insulating Materials and are the direct responsibility of Subcommittee D09.07 on Electrical Insulating Materials.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

***A Summary of Changes section appears at the end of this standard**

IEC Publication 216 Guide for the Determination of Thermal Endurance Properties of Electrical Insulating Materials[4]
IEC Publication 60684 Specification for Flexible Insulating Sleeving[4]
ISO 846 Plastics—Evaluation of the Action of Microorganisms[4]

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions pertaining to electrical insulation, refer to Terminology D1711.

3.1.2 For definitions pertaining to fire standards, refer to Terminology E176.

3.1.3 *heat-shrinkable tubing, n*—tubing that will reduce in diameter from an expanded size to a predetermined size by the application of heat.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *brittleness temperature, n*—the temperature at which 50 % of the specimens fail when the specified number are tested using the apparatus and conditions specified.

3.2.2 *concentricity, n*—the ratio expressed in percent of the minimum wall thickness to the maximum wall thickness.

3.2.3 *longitudinal change, n*—the change in length, either positive or negative, that occurs when the tubing is allowed to freely recover at the recommended recovery temperature, expressed as a percentage of the as supplied or expanded length.

3.2.4 *low-temperature flexibility, n*—the resistance to cracking of tubing when wrapped around prescribed mandrels at specified temperatures.

3.2.5 *restricted shrinkage, n*—shrinkage of the tubing at a prescribed temperature over a specially designed mandrel whose smallest diameter is greater than the fully shrunk size and whose largest diameter is less than the expanded size of the tubing.

3.2.6 *storage-life, heat-shrinkable tubing, n*—the length of time that the tubing will retain its specified expanded and recovered dimensions under storage at a specified temperature.

4. Significance and Use

4.1 These test methods include most of the important tests used to characterize heat-shrinkable tubing. They are intended primarily for, but not limited to, extruded heat-shrinkable tubing.

4.2 It is acceptable to use variations in these test methods or alternate contemporary methods of measurement to determine the values for the properties in this standard provided such methods ensure quality levels and measurement accuracy equal to or better than those prescribed herein. It is the responsibility of the organizations using alternate test methods to be able to demonstrate this condition. In cases of dispute, the methods specified herein shall be used.

NOTE 2—Provision for alternate methods is necessary because of (1) the desire to simplify procedures for specific applications without altering the result, and (2) the desire to eliminate redundant testing and use data generated during manufacturing process control, including that generated under Statistical Process Control (SPC) conditions, using equipment and methods other than those specified herein. An example would be the use of laser micrometers or optical comparators to measure dimensions.

5. Hazards

5.1 **Warning**—*Lethal voltages are potentially present during this test. It is essential that the test apparatus, and all associated equipment that is potentially electrically connected to it, be properly designed and installed for safe operation. Solidly ground all electrically conductive parts that any person might come in contact with during the test. Provide means for use at the completion of any test to ground any parts which: (a) were at high voltage during the test; (b) have potentially acquired an induced charge during the test; or (c) could have retained a charge even after disconnection of the voltage source. Thoroughly instruct all operators in the proper way to conduct tests safely. When making high voltage tests, particularly in compressed gas or in oil, it is possible that the energy released at breakdown would be sufficient to result in fire, explosion, or rupture of the test chamber. Design test equipment, test chambers, and test specimens so as to minimize the possibility of such occurrences and to eliminate the possibility of personal injury. (See Section 23.)*

5.2 *Flammable Solvents:*

5.2.1 Methyl ethyl ketone is a volatile, flammable solvent. It shall be handled in an area having good ventilation, such as a laboratory hood and away from sources of ignition. See Section 100.

6. Selection of Test Specimens

6.1 Select a sufficient number of pieces of tubing in such manner as to be representative of the shipment.

6.2 Cut specimens, free of kinks, from the sample selected under 6.1. Cut perpendicular to the longitudinal axis of the tubing and in such manner that the specimen has cleanly cut square edges.

6.3 Unless otherwise stated, conduct tests on specimens in the completely shrunk condition.

7. Conditioning

7.1 When specified, condition tubing in accordance with Practice D618 using Procedure A, except that a conditioning time of 4 h shall be used. In cases where tests are performed on specimens in the shrunk state, condition the test specimens prior to testing, but after heat shrinking.

DIMENSIONS

8. Significance and Use

8.1 *Inside Diameter*—The inside diameter of tubing before and after heat-shrinking is an important factor in selecting tubing of the proper size to slip easily over an object and to conform tightly after shrinkage.

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

8.2 *Wall Thickness*—Wall thickness measurements are useful in providing design data and in calculating certain physical and electrical properties of the tubing.

8.3 *Concentricity*—In some cases, a thin wall area, due to variation in processing, will lead to equipment failure. It is important, therefore, both in extrusion of the tubing, and its expansion prior to shrinkage in end-use, that concentricity be held above a specified limit to ensure proper performance of the tubing.

8.4 *Length*—The length, both before and after heat-shrinking, is important in the determination of proper fit of the tubing in end-use.

9. Apparatus

9.1 *Mandrels*—Use a series of steel rods suitable for insertion into the tubing including the tapered gages described under Test Methods D876.

9.2 *Micrometers,* mandrel anvil and indicator set accurate to at least 0.001 in. or 0.02 mm.

9.3 *Steel Scale,* graduated in 1⁄64-in. or 0.5-mm divisions.

9.4 *Oven,* forced-convection type, capable of maintaining temperature to within ±5°C.

10. Test Specimens

10.1 Cut three straight lengths of expanded tubing, each 6 in. (150 mm) long, from the sample as directed in 6.2 for each test performed.

11. Procedure

11.1 *Measuring Inside Diameter:*

11.1.1 Select a mandrel that will just fit into the specimen and insert the mandrel into the expanded tubing for a distance of 1 in. (25 mm).

NOTE 3—If the tubing specimens have a tendency to adhere to the mandrels during measurement of diameter, it is recommended that the mandrels be coated with water or talc as a lubricant. However, caution must be exercised not to force the tubing on the mandrel, thereby stretching the specimens.

11.1.2 Using a machinist's micrometer, measure the outside diameter of the mandrel to the nearest 0.001 in. (0.02 mm). Record this as the expanded inside diameter.

11.1.3 Place the specimen in an oven at the temperature specified as suitable for complete shrinkage for a period of time recommended for shrinkage. Make provision for positioning the specimen horizontally in the oven so that recovery can be effected without restriction. If the tubing tends to become sticky at the shrinkage temperature, specimens can be laid in trays that have been powdered slightly with talc.

11.1.4 At the end of the specified shrinkage time, remove the specimens from the oven and allow to cool to room temperature. Measure the inside diameter as described in 11.1.1 and 11.1.2, recording this as the recovered inside diameter.

11.2 *Measuring Wall Thickness:*

11.2.1 Measure the wall thickness of the expanded (as supplied) tubing using a micrometer. By means of a sufficient number of tests, locate the points on the wall corresponding to the minimum and the maximum wall thickness, and record these measurements to the nearest 0.001 in. (0.02 mm).

11.2.2 Allow the specimens to recover under heat as described in 11.1.3 and 11.1.4. Measure the wall thickness as described in 11.2.1 recording these as the recovered thicknesses.

11.3 *Calculating Concentricity*—From measurements of minimum and maximum wall thickness made in accordance with 11.2.1 and 11.2.2, calculate the concentricity (C) of the expanded and recovered tubing respectively, using the following equation:

$$C = 100\left(M''/M'\right) \quad (1)$$

where:

M' = maximum thickness, in. (mm), and
M'' = minimum thickness, in. (mm).

11.4 *Measuring Length:*

11.4.1 Using the steel scale, measure the length to the nearest 1⁄32 in. or 1 mm.

11.4.2 Allow the specimens to recover under heat as described in 11.1.3 and 11.1.4. Measure the length after recovery. Record the length in the expanded and recovered state.

11.5 *Calculating Longitudinal Change*—From the measurements of expanded and recovered length made in accordance with 11.4.1 and 11.4.2, calculate the percent longitudinal change using the following equation:

$$\text{Percent longitudinal change} = 100\left(L'-L''\right)/L'' \quad (2)$$

where:

L' = recovered length, in. (mm), and
L'' = expanded length, in. (mm).

12. Report

12.1 Report the following information:

12.1.1 Identification of the tubing,

12.1.2 Inside diameter of the tubing in the expanded and in the recovered state,

12.1.3 Maximum and minimum wall thickness for each specimen in the expanded and in the recovered state,

12.1.4 Length of each specimen in the expanded and recovered state,

12.1.5 Percentage longitudinal change of each specimen (after recovery) based on the expanded state length,

12.1.6 Concentricity of each specimen in the expanded and the recovered state, and

12.1.7 Time and temperature used for shrinkage of the tubing.

13. Precision and Bias

13.1 The overall estimates of the precision within laboratories, $(S_r)\ j$, and the precision between laboratories, $(S_r)j$, are given in Table 1 for four selected materials. These estimates are based on a round robin of three specimens, each